We claim:

1    1.    A method of evaluating tolerances of computer assisted designs for

2    the manufacture of objects comprising:

3    representing each tolerance zone for each geometric feature of said object by a

4    model with an algebraic form and a geometric form as a tolerance map stored in a

5    computer;

6    computing in said computer interdependencies between said stored maps and

7    interdependencies between submaps of said stored maps to determine how different

8    tolerance zones for said geometric feature affect each other and to determine how

9    different tolerance zones for different geometric features of said object affect each other;

10   and

11   selecting tolerance conditions for said object to optimize allocation of tolerances to

12   each of said geometric features of said object.

1    2.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map representing a plane.

3    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map representing a axis or

3    edge.

1        4.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map representing a

3    cylindrical surface.

1        5.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map representing a position.

1        6.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map representing composite

3    tolerances constructed as a Minkowski sum.

1        7.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map in a space of points of

3    variational possibilities of features of said object.

1        8.    The method of claim 1 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map in a space of points of

3    variational possibilities of features of said object.

1        9.    The method of claim 2 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map in a space of points of

3    variational possibilities of features of said object expressed in Barycentric coordinates.

1      10.    The method of claim 1 where computing in said computer

2    interdependencies between said stored maps and interdependencies between submaps

3    of said stored maps comprises superimposing on a tolerance zone of said geometric

4    feature a tolerance zone specifying parallelism of variations of said geometric feature.


1      11.    The method of claim 1 where computing in said computer

2    interdependencies between said stored maps and interdependencies between submaps

3    of said stored maps comprises superimposing on a tolerance zone of said geometric

4    feature a tolerance zone specifying flatness of said geometric feature.


12.    The method of claim 1 where computing in said computer

2    interdependencies between said stored maps and interdependencies between submaps

3    of said stored maps comprises generating a tolerance zone of an assembled geometric

4    feature for a assembly of at least two objects, each of which objects has a corresponding

5    tolerance zone for corresponding geometric features which are being assembled to

6    comprise said assembled geometric feature.


1      13.    The method of claim 4 where representing each tolerance zone for

2    each geometric feature of said object comprises a tolerance map in a space of points of

3    said object expressed in Pluecker coordinates.

1        14.    The method of claim 3 where representing each tolerance zone for

2     each geometric feature of said object comprises a tolerance map in a space of points of

3     said object expressed in terms of line-solids.


1        15.    The method of claim 4 where representing each tolerance zone for

2     each geometric feature of said object comprises a tolerance map in a space of points of

3     said object for size of cylindrical surfaces is expressed in terms of screw coordinates.


1        16.    The method of claim 1 further comprising establishing a global model

2     by mapping surfaces used as datum or targets in a dimensioning scheme to equivalent

3     control frames in which datum reference frames are rigid sets and validated using degree

4     of freedom algebraic operations, and by representing dimensions and tolerances by the

5     union of corresponding control frames involving the datum and target rigid sets and

6     corresponding tolerance classes.


1        17.    The method of claim 16 wherein mapping surfaces used as datum or

2     targets in a dimensioning scheme to equivalent control frames comprises forming datum

3     reference frames as rigid sets for target features and feature patterns.


1        18.    The method of claim 17 wherein mapping surfaces used as datum or

2     targets in a dimensioning scheme to equivalent control frames in which datum reference

3     frames are formed as rigid sets for a circular pattern of bolt holes.

1    19.    The method of claim 16 further comprising identifying redundant or

2    conflicting restraints by using a degree of freedom algebra on control frames by

3    determining whether the corresponding datum reference frame is a rigid set and the

4    maximum degrees of freedom which said datum reference frame controls.


1        20.    An apparatus for geometric variations to integrate parametric CAD

2    with tolerance analysis and optimization of a manufactured object comprising a computer

3    wherein is stored:

4        a geometry engine module E1 to generate a B-rep solid model of said object;

5        a constraint solver E2 to generate a D&T graph of said object;

6        a geometry engine system M1 communicated to said geometry engine module E1

7    and constraint solver E2;

8        a dimensioning module M2 for receiving said B-rep solid model and said D&T

9    graph as input data;

10        a tolerancing module M4 communicating with said dimensioning module M2;

11        a global visualization module M3 communicating with said tolerancing module M4;

12        a D&T Schema Advisor module M5 communicating with said tolerancing module

13    M4;

14        a tolerance allocation module M6 communicating with said tolerancing module M4;

15        a local model visualization module M7 communicating with said tolerance allocation

16    module M6 for providing a geometric visualization of tolerancing of said object; and

17        a statistical tolerance analysis package E3 communicating with said tolerance

18    allocation module M6 for providing an algebraic visualization of tolerancing of said object.